TITLE OF INVENTION

A CLOSURE FOR SHIELDING THE TARGETING ASSEMBLY OF A PARTICLE ACCELERATOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not Applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable

BACKGROUND OF THE INVENTION

1. Field of Invention

[0003] This invention relates to radiation shielding for the targeting assembly of a cyclotron or particle accelerator used in a radiopharmaceutical or radioisotope production system. More specifically, the present invention is related to a closure which is mounted on the housing of a particle accelerator or cyclotron, and which serves as radiation shielding for, and provides access to, such targeting assembly.

2. Description of the Related Art

Positron Emission Tomography (PET) is a powerful diagnostic tool which allows the imaging of biological functions and physiology. PET utilizes short-lived radioactive isotopes, commonly referred to as tracers, which are injected into a patient's body. These radioisotopes are produced by radioisotope production systems which incorporate particle accelerators or cyclotrons. The particle accelerators produce radioisotopes by accelerating a particle beam and bombarding a target material. The typical particle accelerator used for producing PET radioisotopes includes a targeting assembly which is accessible from outside of the housing of the

accelerator, and generally through an access opening in the housing, such that the target material can be replaced and such that maintenance can be performed on the targeting assembly. In order to protect those operating and maintaining the accelerator from the radiation emanating from the accelerator, the entire accelerator is placed in a shielded enclosure. For example, such shielded enclosures often take the form of a shell which surrounds the accelerator or cyclotron, with the shell being provided with movable portions or doors to provide access to the accelerator. The shielded enclosures typically include a high-Z shielding material, such as lead, adjacent the accelerator to moderate neutron energy and shield against gamma radiation, and a low-Z outer shielding, such as concrete, to absorb neutrons and, again, to provide gamma shielding. Commonly, the high-Z shielding defines a greater thickness proximate the targeting system of the accelerator given the neutron energy typically emanating therefrom. Generally, such shielded enclosures provide the only shielding about the targeting assembly of the accelerator such that when the shielded enclosures are removed or opened the targeting assemblies are accessible, but unshielded. Further, typical shielding enclosures for particle accelerators have a gap greater than one inch (>1") between the shielding and the accelerator/target assembly. This is due to the manufacturing tolerances of the shielding materials involved, and the methods for shield motion. Neutrons can be transported through these gaps without being moderated, allowing higher radiation doses outside the shield assembly.

[0004] An example of one approach to providing shielding for an accelerator used in conjunction with a radioisotope production system is disclosed in U.S. Patent No. 6,392,246 B1. The apparatus disclosed therein provides an outer housing which shields not only the accelerator, but various other components of the radioisotope production system. Further, U.S. Patent No. 5,037,602 discloses a radioisotope production facility, and

discusses the need for thick shielding around the accelerator to confine radiation. See also, U.S. Patent Nos. 6,433,495 B1; 5,874,811; 5,482,865; and 4,646,659.

[0005] Radioisotope production systems are commonly located in hospitals and other healthcare facilities such that the radioisotopes are readily available for use in medical imaging. Accordingly, it is imperative that proper radiation shielding be provided to protect not only the operators of the system and the medical staff, but the public. However, the need for thick radiation shielding around the accelerator tends to make radioisotope production systems large, space consuming systems, and the shielding tends to be very heavy. The size and weight of the radioisotope production systems tends to limit the nature of the facilities in which the systems can be placed, and often the construction of special facilities to accommodate the systems is necessary. Thus, it is advantageous to limit the thickness of the shielding surrounding the accelerator to the extent that it can be done without compromising the effectiveness of the shielding. Further, particularly where the radioisotope production system is placed in a healthcare facility, the exposure of the targeting system when the shielded enclosure surrounding the accelerator is removed can be particularly problematic. For example, where access to components of the accelerator other than those associated with the targeting system is required, the removal or the opening of the shielded enclosure leaves the targeting system unshielded, thereby unnecessarily increasing the level of radiation emanating from the accelerator. Additionally, it is advantageous to make shielding that conforms more closely to the accelerator and target envelope, to force the moderation of initially energetic neutrons.

BRIEF SUMMARY OF THE INVENTION

The present invention provides a closure for shielding, and selectively providing access to, the targeting assembly of the particle accelerator of a radioisotope production system. The typical radioisotope production system which utilizes the closure of the present invention includes a shielded enclosure which surrounds the particle accelerator and provides selective access to the particle accelerator. The closure of the present invention includes at least one door, and in one embodiment first and second doors, for selectively covering the opening in the housing of the particle accelerator. This closure, by virtue of being mounted directly on the accelerator, has a much smaller gap (< 1/8") between the shielding material of the closure and the accelerator, forcing the moderation of neutrons. This makes the additional shielding more effective, and, therefore, smaller and lighter than would otherwise be possible. The doors are movable from a closed position whereby the targeting assembly is shielded, to an open position whereby access to the targeting assembly is provided. In one embodiment, each first and second door is fabricated of copper. The closure also includes a door mounting assembly for mounting the doors on the housing of the particle accelerator. In one embodiment the door mounting assembly includes a frame for being secured about the opening in the particle accelerator accessing the targeting assembly. The door mounting assembly also including a first hinge assembly for pivotally securing the first door to the frame and a second hinge assembly for pivotally securing the second door to the frame, whereby the first and second doors of the closure selectively cover, and reduce radiation emissions from, the opening in the housing of the particle accelerator and the targeting assembly therein. Thus, the particle accelerator can be accessed by opening or removing the shielded enclosure surrounding the accelerator while maintaining radiation shielding over the targeting assembly.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0006] The above-mentioned features of the invention will become more clearly understood from the following detailed description of the invention read together with the drawings in which:

FIG. 1 is a perspective view of a closure for shielding the targeting assembly of a particle accelerator in accordance with the present invention;

FIG. 2 is a side elevation view of a radioisotope production system of the type that would utilize the closure of the present invention;

FIG. 3 is a top plan view, in section taken at 3-3 of **FIG. 2**, of a radioisotope production system with two closures in accordance with the present invention mounted on the particle accelerator;

FIG. 4 is a perspective view of a closure for shielding the targeting assembly of a particle accelerator in accordance with the present invention;

FIG. 5 is a rear perspective view of a closure for shielding the targeting assembly of a particle accelerator in accordance with the present invention;

FIG. 6 is a partial perspective view of a closure for shielding the targeting assembly of a particle accelerator in accordance with the present invention;

FIG. 7 is a partial perspective view of a closure for shielding the targeting assembly of a particle accelerator in accordance with the present invention;

FIG. 8 is a partial perspective view of a closure for shielding the targeting assembly of a particle accelerator in accordance with the present invention; and

FIG. 9 is a partial top plan view, in section, of the doors of a closure for shielding the targeting assembly of a particle accelerator in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0007] A closure for shielding, and selectively providing access to, the targeting assembly of a particle accelerator in accordance with the present invention is illustrated generally at **10** in **FIGS. 1, 3-5** and **7**. The closure **10** is used to shield the target assembly of the particle accelerator of a radioisotope production system. An example of a typical radioisotope production system of the type which would utilize the closure **10** is illustrated at **12** in **FIGS. 2** and **3**. As illustrated in **FIG. 3**, the radioisotope production system **12** incorporates a particle accelerator **14** enclosed in a housing **16**, and includes a shielded enclosure **17** which surrounds the accelerator **14**. In this particular system **12** the shielded enclosure **17** includes stationary shield assemblies **18** and **20** which are provided on opposite sides of the accelerator **14**, and includes oppositely disposed movable shield assemblies **22** and **24** which can be moved away from the accelerator **14** to provide access to the accelerator. However, the particle accelerators with which the closure **10** can be used may utilize various shield enclosure configurations. Further, the illustrated particle accelerator **14** incorporates two target changers, and, accordingly, two closures **10** are utilized. It will, however, be understood that the closure **10** can be utilized with particle accelerators having single or multiple targeting assemblies. It will also be noted that the movable shield assemblies **22** and **24** include an inner shield **26** of high-Z shielding material, such as, for example, lead epoxy, and an outer shield **28** of low-Z shielding material, such as, for example, concrete.

[0008] The closure **10** is provided with a door mounting assembly which, as will be discussed in detail below, facilitates the mounting of one or more doors for accessing the targeting assembly of an accelerator. As best illustrated in **FIGS. 1** and **4** through **6**, in one embodiment the door mounting assembly includes a frame **30** which is defined by a sill member

32, a header member **34**, and opposite jamb members **36** and **38**. The frame **30** is secured to the housing **16** of the particle accelerator **14** about an opening **40** (see **FIG. 6**) provided in the housing **16** through which the targeting assembly **42** of the accelerator **16** is accessed. The sill member **32**, header member **34**, and jamb members **36** and **38**, are provided with counter sunk openings **39** which extend through the frame **30** and allow the frame **30** to be bolted to the housing **16** of the accelerator **14** with suitable bolts (not shown). As will be discussed further below, the frame **30** is fabricated from a suitable radiation shielding material. In one embodiment the shielding material used is copper, but other materials could be used.

[0009] Mounted on the frame **30** is at least one closable door, and in the illustrated embodiment two doors **44** and **46** are mounted on the frame **30** such that the opening defined by the frame **30** can be selectively closed. The door **44** is pivotally secured to the frame **30** at its outboard edge **48** with a hinge assembly **50**, and the door **46** is pivotally secured to the frame **30** at its outboard edge **52** with a further hinge assembly **54**. The various components of the hinge assemblies **50** and **54** are fabricated of a strong, durable material, such as, for example, steel. As will be discussed further below, the doors **44** and **46** are fabricated from a suitable radiation shielding material, and in one embodiment the shielding material used is copper. However, other radiation shielding materials could be used. Moreover, it is contemplated that alternative door mounting assemblies could be used to mount the doors **44** and **46** on the particle accelerator instead of the frame **30**. For example, the doors **44** and **46**, or a single door, could be mounted directly on the housing **16** of the particle accelerator **14** using suitable hinge assemblies.

[0010] In the illustrated embodiment, the sill member **32** defines a rabbet **56** along the upper portion of its front edge. The rabbet **56** receives the lower inner edge portions of the doors **44** and **46** when such doors are

in a closed position. Also, the header member **34** defines a rabbet **58** along the lower portion of its front edge which receives the lower inner edge portions of the doors **44** and **46** when such doors are in a closed position. Further, the doors **44** and **46** are mounted such that they close over the front surfaces **60** and **62** of the jamb members **36** and **38**, respectively. It will also be noted, as illustrated in **FIG. 9**, that the door **44** is provided with a rabbet **64** along the outside of its inboard edge, and the door **46** is provided with a rabbet **66** along the inside of its inboard edge, such that when the doors **44** and **46** are in a closed position the doors overlap proximate their inboard edges. Also, it will be noted that the sill member **32**, the header member **34**, and the jamb members **36** and **38** are matched dimensionally to the accelerator **14** and housing **16**, providing substantially no gaps for radiation to emanate from or through. As a consequence of the use of the rabbets **56**, **58**, **64** and **66**, and the positioning of the doors **44** and **46** over the front surfaces **60** and **62** of the jamb members **36** and **38**, any radiation emanating from the targeting assembly **42**, or the opening **40** in the housing **16**, is intercepted by the radiation shielding material from which the doors **44** and **46**, and the frame **30**, are fabricated, and there are no openings or seams between the frame **30** and the doors **44** and **46** which would offer an unobstructed linear radiation path exiting the closure **10**.

[0011] The closure **10** is also provided with a locking mechanism which selectively secures the doors **44** and **46** in a closed position. It will be recognized by those of ordinary skill in the art that various locking mechanisms could be used, such as, for example, various latch or bolt mechanisms typically used to secure doors. However, in one embodiment the securing mechanism includes a pair of removable securing pins **68** and **70**, which are received through holes **72** and **74** in the header member **34**. The holes **72** and **74** register with holes in the doors **44** and **46** (only one such hole being shown at **76** in **FIG. 8**) when such doors are in a closed

position. Accordingly, the doors **44** and **46** can being selectively secured in the closed position by inserting the pins **68** and **70** through the holes **72** and **74** in the header member **34**, and into the holes **76** in the doors **44** and **46**. To facilitate the removal of the pins **68** and **70**, such pins are provided with pull rings **71**.

[0012] It is also anticipated that one or both of the doors **44** and **46** of the closure **10** can be provided with contoured inner surfaces which are configured to be closely received over components of the targeting assembly of the particular particle accelerator. For example, as illustrated in **FIGS. 5** and **8**, the door **46** is provided with an inner surface which defines a recess **78** which closely receives components of the targeting assembly **42**.

[0013] As noted above, in one embodiment the frame **30** and doors **44** and **46** of the closure **10** are made from copper. In this regard, testing has disclosed that the use of copper for such components of the closure **10** permits the thickness of the inner shield **26** of the shielded enclosure **17** to be reduced. For example, in tests to determine the desired relative thickness of the copper shielding material of the closure **10** and the lead epoxy shielding **26** of the shielded enclosure 17 necessary to maintain a 0.25 mrem/hr target radiation dose, the following results were obtained:

Copper Thickness (cm)	Lead Epoxy Thickness (cm)
0	40
2	35
4	30
6	26
8	23
10	20

Accordingly, whereas 40 cm of lead epoxy was required to maintain the target dose, by adding 10 cm of copper shielding over the target assembly, the thickness of the lead epoxy shielding could be reduced to 20 cm, reducing the combined thickness of the copper and lead epoxy shielding to 30 cm. Thus, whereas the thickness of the various components of the closure **10** can vary, it will be understood that the use of copper as the fabricating material for the closure **10** allows the combined thickness of the shielding for the accelerator to be reduced, allowing a reduction in the size of the radioisotope production system. This notwithstanding, it is contemplated that various other fabricating materials can be used for the components of the closure **10**, such as, for example, stainless steel, lead, or aluminum, and it is contemplated that various alloys of copper could be used. Moreover, it is contemplated that the doors **44** and **46** could incorporate, and the frame **30**, could incorporate layers of copper, or copper alloy, shielding rather than being fabricated entirely of copper, or a copper alloy.

[0014] In light of the above, it will be recognized that the closure **10** provides a separate shielding for the targeting assembly **42** of the accelerator **14**, while still allowing access to the targeting assembly. When the shielded enclosure **17** is opened, as in when the movable shield assemblies **22** and **24** are moved away from the accelerator **14**, the targeting assembly **42** remains shielded by the closure **10**. Accordingly, where access to the accelerator **14** is required, but not to the targeting assembly **42**, the doors of the closure **10** can remain closed in order to reduce radiation emissions. Moreover, the use of a closure **10** fabricated of copper, or a copper alloy, permits the thickness of shielded enclosure **17** surrounding the accelerator to be reduced, thereby allowing the radioisotope production system **12** to be smaller in size.

[0015] While the present invention has been illustrated by description of several embodiments and while the illustrative embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. The invention in its broader aspects is therefore not limited to the specific details, representative apparatus and methods, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of applicant's general inventive concept.